

Assemblage Definition, Analytic Methods, and Sources of Variability in the Interpretation of Marquesan Subsistence Change



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EVER SINCE THE 1840S, when bones of extinct moa were discovered in association with human artifacts in New Zealand, prehistorians of Polynesia have been alive to the prospect of documenting patterns of faunal change with archaeological assemblages. The last 150 years have seen much progress in faunal change studies. Improvements in excavation and recovery techniques have enabled archaeologists to identify changes in virtually every component of faunal assemblages. Patterns of change in the abundance of large animals, such as the moa, are now complemented by the recovery and investigation of the remains of animals as small as songbirds (e.g., Olson and James 1982, 1984; Steadman 1989*a*) and land snails (Christensen and Kirch 1986). Indications of change over time in virtually every component of faunal assemblages are reported throughout Polynesia. Findings include the extinction or extirpation of large edible birds (Anderson 1983, 1989; Olson and James 1982, 1984; Steadman 1989*a*, 1989*b*, 1992; Steadman and Pahlavan 1992; Steadman et al. 1990), iguanas (Pregill and Dye 1989), and marine mammals (Smith 1986); decline in the sizes of fish (Leach and Boocock 1994) and shellfish (Anderson 1981; Poulsen 1987; Spennemann 1987); changing relative abundances of fish taxa (Allen 1992; Leach and Boocock 1993; Leach and Davidson 1988:18–20); decline in the relative abundance of marine turtle (Dye and Steadman 1990; Kirch and Dye 1979; Kirch and Yen 1982); and increases, at times followed by decline, in the relative abundances of domesticated dogs and pigs (Dye and Steadman 1990; Kirch 1984:160; Kirch and Yen 1982:281).

Accumulation of new data has been accompanied by greater sophistication in the interpretive analyses designed to explain observed patterns of change. In general terms, it is possible to speak of two main interpretive foci in the study of Polynesian archaeological faunas. The first, prefigured by the discovery of the extinct moa, has to do with deriving inferences about changes in the absolute abundances of taxa in the environment from changes in the relative abundances of taxa in archaeological faunal assemblages. Here, the potential of cultural selec-

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tion to produce a biased sample of taxa in the environment is only the most obvious problem. Further difficulties are introduced by the extreme plasticity of ecological relations within the environment, such that changes in the relative abundances of taxa in an archaeological assemblage bear no obvious or necessary relationship to changes in the absolute abundances of those taxa in the environment (Grayson 1984:18–20). The second interpretive focus infers changes in subsistence from patterns of change in archaeological faunal assemblages. Although the chain of inference can be more direct here—specimens in archaeological faunal assemblages usually represent food remains, and the nutritional requirements of the human body place some constraints on the role of meat in the diet—the analysis is by no means straightforward. The sheer number of intervening variables related to preservation, recovery, fragmentation, identifiability, intrasite variability, and cultural disposal patterns makes the possibility of confident inferences about the exact role of meat in the diet somewhat remote. Still, progress is being made in New Zealand by Leach and his associates, who have devised a method for the accurate estimation of meat weight from identifiable skeletal elements of a snapper (Leach and Boocock in press) and have employed a method for estimating from stable isotope ratios in human bone the relative contributions of various types of foods to the diet (Leach et al. in press).

Fortunately for the prehistorian, it is not always necessary to make confident inferences about the absolute contributions of faunal taxa to an archaeological assemblage in order to learn something interesting about subsistence change. Often, changes over time in the relative contribution of faunal taxa to the diet can be inferred fairly directly from archaeological faunal assemblages, and confidence in these inferences can be bolstered by coeval evidence for change in other data sets. This evidence might come from the archaeological record, as when the relative abundance of a specialized tool used to capture a certain taxon varies directly with the relative abundance of that taxon in an archaeological assemblage. Often, however, it comes from sources such as the historic record, as in the case of the moa, where relatively comprehensive observations on the composition of New Zealand's avifauna proved that birds the size of the moa were no longer extant and so must have been extinguished sometime before compilation of the historic record.

Sweeney and colleagues (1993) have argued that at least some of this progress in the investigation of subsistence change in Polynesia might be illusory. Specifically, they dispute the long-standing hypothesis that prehistoric Marquesan subsistence changed substantially over time (*pace* Dye 1990; *pace* Kirch 1973). They question whether a significant portion of the observed variability in Marquesan faunal assemblages reflects spatial and functional variability between sites rather than change over time. They suggest that some of the apparent variability is due to the use of inappropriate faunal analysis techniques and to "predilections of change [that] take on much of the interpretive and empirical burden" (Sweeney et al. 1993:235). They believe that these factors have led prehistorians to generalize particular patterns of change before these patterns are "sufficiently verified for Polynesian prehistory" (Sweeney et al. 1993:226). Based on a reanalysis of faunal remains from the Hane Dune site, and the results of faunal analyses at single sites in Hawai'i, the Cook Islands, and Samoa, they suggest that "stable patterns of fau-

nal resource use may be more common, rather than the exception in Polynesian prehistory" (Sweeney et al. 1993 : 235).

This paper shows that the difficulties adumbrated by Sweeney and colleagues and the solutions they propose are, for the most part, unconvincing and lead faunal analysis away from the possibility of reliably inferring subsistence change from archaeological faunal assemblages. Although methodological problems do loom large, analyses of archaeological faunal remains in the Marquesas have historically been constrained primarily by a paucity of data and not by analytic methods. As the Marquesan case shows, growth of the data base makes it possible to exercise increasing control over intervening sources of variability. Throughout this process, generalizing statements about what happened in prehistory based on indications of change in the archaeological record are useful constructs, whether or not they have been "sufficiently verified." Conclusions drawn from research today become the hypotheses that guide research tomorrow. Stating research conclusions in the context of prehistory helps keep archaeological work focused on the larger goals of describing and explaining what happened in the past. The hypotheses of change in Marquesan prehistory put forward by Kirch (1973) and Dye (1990) do not have to be abandoned until they are verified. Their main features have been bolstered by the results of recent excavations in the Marquesas, and they retain their places as the working hypotheses of change in Marquesan subsistence.

BACKGROUND

Kirch (1973) is an early example of the ecological interpretation of Pacific island prehistory. A result of research conducted for a graduate seminar at the University of Hawai'i in 1970, the paper was based on the identification of faunal and floral material from seven archaeological sites on Ua Huka and Nuku Hiva islands in the northern Marquesas that were excavated by Sinoto and Kellum in 1964 and 1965 (Sinoto 1966; Sinoto and Kellum 1965). Faunal data from five of the sites—the Hane Dune site (MUH1), the Manihina Dune site (MUH2), the Vaipikoau Cave site (MUH4), the Vaipikoau Shelter site (MUH5), and the Ha'atuatua site (MN1, previously excavated by Suggs [1961] and labeled by him NHaa1)—are presented in a series of tables (Kirch 1973 : Tables 1–5, 7, 9). The identified and tabulated materials represent samples of the faunal assemblages recovered during excavation and include materials from five excavation units at the Hane Dune site, including three units from Area A and two units from Area B; single units at Manihina Dune and Vaipikoau Shelter; two units at Ha'atuatua; and an unidentified number of units at Vaipikoau Cave. About one-half of the marine shell by weight was identifiable to one of five families, and most of the bone was identifiable to one of six taxa, including human, pig, rat, bird, turtle, and fish. Also identified were crustaceans, sea urchins, and chitons. Supplementary tables identify fish material from area B at the Hane Dune site (Kirch 1973 : Table 6), and plant remains preserved in the dry sediments of the Vaipikoau Cave site (Kirch 1973 : Table 8).

When the identified faunal materials were arranged by time period, based on the then current understanding of the relative chronology of the excavated northern Marquesan sites, clear patterns of change were apparent in the relative abun-

dances of taxa in the faunal assemblages (Kirch 1973 : Figure 3). Most prominent are declines in the relative abundances of bird, turtle, and chiton, and increases in pig. These patterns of change suggested to Kirch "a shift from hunting and gathering techniques to sedentary agricultural and animal husbandry practices" (1973 : 38). Interpreted in an ecological framework, "a primarily agronomic procurement system became more adaptive than the preceding marine-oriented system" (Kirch 1973 : 38).

The goal of Dye (1990) was to develop an alternative to the ecological interpretation of Pacific prehistory, one that recognizes the possibility that change was not always "adaptive," but could be "maladaptive" for large portions of the population. The paper, presented to a symposium at the Fifteenth Pacific Science Congress in 1983, was based on the identification of fish bones from three sites: the Hane Dune site in the northern Marquesas and the Hanapete'o Cave (Skjolsvold 1972) and Hanatukua sites on the island of Hiva Oa in the southern Marquesas. The 651 bones reported in Dye (1990 : Table 1) were identified to the family level, with the exception of the Elasmobranchii whose vertebrae and teeth are easily identifiable but often difficult to assign to family, and Carangidae, specimens of which were confidently identified as either runnerfish, scadfish, or jackfish. The identified taxa were further divided into two categories by habitat: "bottom-dwelling and inshore" taxa, including relatively small and weak fish whose capture places minimal demands on fishing gear, and "free-ranging and pelagic" taxa, including larger, stronger fish whose capture generally requires a combination of capable gear, special skill, and some good luck (Dye 1990 : 74).

Arranging the identified taxa by time periods reveals a clear pattern of decline over time in the relative abundance of free-ranging and pelagic fishes. This decline coincided with changes in the kinds and sizes of fish hooks produced in the Marquesas, where the larger rotating hooks designed for the capture of taxa among the free-ranging and pelagic fish were gradually replaced by small jabbing hooks designed for the capture of taxa among the bottom-dwelling and inshore fish. A decrease in the relative abundance of free-ranging and pelagic fish did not "rule out the possibility that Marquesan fishermen were in fact becoming more productive because inshore fishing provided greater returns on labour than did offshore angling" (Dye 1990 : 75). Because changes in the relative abundances of taxa provide a weak basis for inferences about absolute abundances, the faunal data published by Kirch (1973) and by Kellum (Skjolsvold 1972) were reviewed to assess the changing importance of fish relative to other flesh foods in the Marquesan diet. In contrast to remains of pig and shellfish, the other two flesh foods popular at the end of Marquesan prehistory, the relative abundance of fish bone in the faunal assemblages did not increase over time. This was cited in support of the thesis that Marquesan subsistence strategies were "maladaptive" for a large portion of the population.

The ethnographic data support the picture of a poorly developed Marquesan fishing industry, a curious state of affairs in a place where drought frequently crippled terrestrial food production. . . . Instead of designing and manufacturing a fine fleet of fishing vessels and employing an underutilised labour force to harvest the spontaneous products of the sea, a small group of influential men apparently monopolised a paltry collection of leaky dugout canoes for their own use and enjoyment. When the droughts came people starved. (Dye 1990 : 79)

ASSEMBLAGE DEFINITION

A faunal assemblage is an archaeological construct that groups faunal specimens on the basis of some presumed similarity. Grayson refers to the process of assemblage definition as "aggregation" (1984:17n.). The same set of specimens might be aggregated in different ways depending upon the research question at hand. For example, research designed to test the influence of environmental variability on subsistence practices might aggregate all the faunal remains from a site as a single assemblage and compare this to an assemblage from a site in a different environment. An investigation of subsistence change over time might aggregate these same remains into several assemblages according to their stratigraphic positions. In a regional study, the remains might be aggregated with remains from several other sites within the region. Precisely how specimens are aggregated into assemblages depends primarily on the research question of interest, but this is rarely the only consideration faced by the analyst. Often, decisions about where to draw the boundary of an assemblage are also constrained by the sizes of available faunal collections. A small assemblage often has striking characteristics that are not possessed by the population from which it was drawn, but are due instead to a variety of factors that statisticians lump under the rubric of "chance." Assemblage definition must balance these two, often conflicting, requirements: it must capture the variability of interest while controlling wherever possible variability from other sources, and it must maintain a sufficiently large number of specimens to sustain confidence that the assemblage reflects the characteristics of the population from which it was drawn.

Sample size was a concern that both Kirch and Dye addressed when they defined the assemblages upon which their inferences were based. Their goal was to identify changes over time in Marquesan faunal assemblages, and they both used assemblages drawn from a variety of sites, assuming that the sites together would reveal regional patterns of change rather than idiosyncratic differences due to space and function. Neither claimed that the indications of change discovered were apparent at the Hane Dune site alone (*pace* Sweeney et al. 1993:231). Although specimens were identified to various taxonomic levels—Kirch used rather broad taxa, and Dye generally identified fish to family—neither Kirch nor Dye chose to base inferences on changes in the relative abundances of the identified taxa. Instead, they aggregated the identified taxa into a smaller number of taxa, thereby increasing sample sizes. Dye (1990) classified the identified taxa as either "free ranging and pelagic" or "inshore and bottom-dwelling"—a classification that is misrepresented by Sweeney and colleagues (1993:233)—thereby reducing the number of taxa from 24 to 2. He also divided the four-phase Marquesan prehistoric sequence, only three phases of which were represented in the faunal remains, into two periods. Thus, a potential division of the assemblage into 72 parts (3 periods and 24 taxa) was rejected in favor of a division into just 4 parts with a corresponding increase in the numbers of specimens assigned to each taxon. The steps taken by Kirch are less dramatic, but he did lump chiton, sea-birds, and turtles as marine taxa, contrasting these with the terrestrial taxon, pig. The classification favored by Sweeney and colleagues, which uses biologically defined taxa, glosses over the point that taxa useful in the study of biology might not be well suited to the investigation of particular archaeological problems, where

categories based on differences in microenvironments exploited, techniques used, and nutrition might be more appropriate (Cowgill 1989: 135). Dye's classification based on capture technique, since elaborated by Rolett (1989), and Kirch's classification by environment both ameliorate the small-sample problem and focus the analysis on aspects of variability that are meaningful for prehistory.

Sweeney and colleagues were concerned that it be "possible to control for spatial and possibly functional effects on the procurement and deposition of faunal remains" (1993: 231), so they limited their reanalysis to a single site. They chose the Hane Dune site because it spans "virtually the entire sequence of Marquesan prehistory" and because "the separation of the site's stratigraphy into early and late components is well established" (Sweeney et al. 1993: 227; but see Anderson et al. 1994). Despite the "well established" separation of the site's stratigraphy, they reassigned layers from some excavation units to different periods than those established in the literature, and this is reportedly responsible for the discrepancies between their data tables and those published by Kirch (Graves pers. comm. 1995). Unfortunately, the new correlation of layers was not published, so it cannot be evaluated. Anderson and colleagues reconsidered the Hane Dune site stratigraphy in detail; their proposal for a new correlation of layers makes very little difference in the distribution of faunal remains over time (1994: 48–50). For this reason, and because there are omissions in the data taken from Dye (1990), it is recommended that the original data tables be used, at least until the stratigraphic reanalysis is published. Unless specifically noted otherwise, all references in this paper are to the data sets as originally published.

Although it is certain that spatial variation is controlled by reanalyzing remains from a single site, a case can be made for both sides of the issue of functional change at the Hane Dune site. Anderson and colleagues have recently argued for persistence of functional differentiation between Areas A and B, separated by only 20–40 m, over the span of the site's occupation, the duration of which is still a matter of debate but is probably greater than 1000 years (Anderson et al. 1994; Kirch 1986). On the other side is the hiatus in occupation at both major excavation areas, illustrated most graphically by the layer of clean sand, 80 cm thick, at Area B that lacks the concentrated occupation refuse of the cultural deposits beneath and above it, but which contains human burials (see Anderson et al. 1994; Sinoto 1966: Fig. 1). This sand layer coincides with Sinoto's Phase III (Sinoto 1979), which is conspicuous for its lack of faunal data (see Dye 1990: 81, 76n.3). Great changes in Marquesan society are believed to have been taking place at the time this clean sand layer was deposited, including changes in settlement pattern (Suggs 1961: 182–184) and increases in social stratification and warfare (Suggs 1960: 119–124). In these circumstances, one might expect that reoccupation of the site after a hiatus would not be functionally identical to an earlier occupation, thus lending weight to the hypothesis that the function of the Hane Dune site was not static, but instead changed over time.

The decision to analyze only the Hane Dune site brings with it considerable reduction in sample size, particularly for younger deposits. For the faunal data reported by Kirch (1973) there is no change in the Period I remains, a modest 5 percent drop (143 gm) in Period II, but a reduction of 57 percent (5792.3 gm) for Period IV. The fish-bone data excluded by this decision are the early-period remains from Hanatukua ($n = 24$), the late-period remains from Hanapete'o

($n = 223$), and Balistidae from the Hane Dune site ($n = 3$), the latter apparently inadvertently. After these adjustments, Sweeney and colleagues claim that “nearly 500 elements were identifiable by Dye” (1993: 231), but their Table 3 contains a grand total of only 401 number of identified specimens (NISP) out of the 651 NISP tallied in Dye (1990: Table 1), with the late-period assemblage falling from 323 NISP to just 99 NISP, a reduction of 69 percent.

METHODOLOGICAL CRITICISMS

A major point raised by Sweeney and colleagues concerns the significance of analytic methods in faunal studies (1993: 234). Drawing on the work of Grayson (1984), they introduce new methods to the study of Marquesan fauna, including the use of Spearman's rank correlation coefficient for measuring the similarity of assemblages, and various measures of diversity. In their view, these methods represent advances over older, “flawed” methods (Sweeney et al. 1993: 226), with the implication that the new methods should replace the old. Because the future of faunal analysis is tightly linked to advances in method, this is an important claim and one worth examining in detail.

A broad criticism of Sweeney and colleagues with potential for far-reaching effects on faunal analysis in Polynesia concerns the use of relative proportions, or percentage frequencies. Dye's inferences about changes in Marquesan fishing were based on the observation that the relative proportions of inshore and bottom fish versus free-ranging and pelagic fish in the early period were reversed in the late period. Similarly, Kirch's interpretations were based on a graph showing the relative proportions of taxa over time. Sweeney and colleagues (1993) criticize these procedures on the basis that analyses of percentage frequencies lead to the problem of “closed arrays.”

Since percentages must sum to 100, the fact that the relative abundance of one taxon increases at the same time that the relative abundance of another decreases may be telling us more about the constraints imposed by closed arrays than about the behavior of the variables in which we are really interested. (Grayson 1984: 19)

What is the variable of interest? According to Sweeney and colleagues, the variable of interest is the “absolute abundance” of a taxon (1993: 230), by which is meant the number of individuals that contributed bones to an assemblage. But this is not what Kirch and Dye had in mind. Instead, their analyses, like those of faunal analysts generally (Grayson 1984: 25), have to do with the *relative* abundances of taxa—either to the midden content of sites (Kirch 1973: 36) or to subsistence (Dye 1990: 75–77)—and to changes in them over time. It might be the case, for instance, that the absolute number of birds eaten in the Marquesas each year, x , did not vary, but this is less interesting for prehistory than the fact that x birds constituted 90 percent of the meat eaten during Period I, but less than 1 percent in Period IV. Kirch and Dye use percentage frequencies because this is a variable of particular use and interest. Inferences about absolute abundances are peripheral to their interpretations. The criticism based on the problem of closed arrays is not valid because it misidentifies the variable of interest. Faunal analysts in Polynesia interested in subsistence change will continue to investigate the relative proportions of taxa in faunal assemblages.

Neither Kirch (1973) nor Dye (1990) performed statistical tests of the patterns they interpreted as changes in Marquesan subsistence. Implicit in this are the presumptions that the observed patterns are not simply matters of chance and that sources of variability unrelated to time do not have an overwhelming effect. The patterns are thus *indications* that something interesting might be going on (Mosteller and Tukey 1977:25–27). It is desirable to move beyond indications by determining with statistical techniques that the observed indications are unlikely to be due to chance. Grayson (1984) has made the case that rank-order statistics are particularly well suited to this task in the context of faunal analyses. Sweeney and colleagues (1993) introduce the use of rank orders to faunal analysts in Polynesia with two examples.

The reanalysis by Sweeney and colleagues of the faunal assemblages at the Hane Dune site identified by Kirch (1973) is restricted to observations about the rank-order abundances of taxa. They treat the weight data reported by Kirch on an ordinal scale because “Grayson . . . demonstrated that faunal data are nominal to ordinal scale variables at best” (Sweeney et al. 1993:230). Actually, Grayson demonstrated that two counting methods, minimum number of individuals (MNI) and NISP, do not directly reflect the number of individuals that contributed bones to an assemblage—the “absolute abundance” of taxa—but do, in most circumstances, correctly estimate the rank order of the absolute abundances. Sweeney and colleagues make no attempt to extend this argument to weights, but proceed as if this can be done. Their reanalysis is summed up in the claim that “the major taxa (excepting bird) show no shift over time in their rank order abundances” (Sweeney et al. 1993:231), but this statement is untrue. Referring to the original data, summarized in Table 1, birds do show the greatest shift in rank order over time, but fish, shell, and pig increase in rank, and turtles decline. The category of marine invertebrate—a taxon that combines Kirch’s original categories of urchin, chiton, and crustaceans—changes in rank-order abundance, but without a consistent direction. The basis for classifying the changes in rank-order abundance of birds alone as a “shift” is not made clear, so the method used by Sweeney and colleagues in this instance cannot serve as an example for other faunal analysts.

The reanalysis of the fish-bone data by Sweeney and colleagues is more involved and, with its application of the Spearman rank correlation coefficient, potentially more important to faunal analysts interested in the application of new methods. It begins with the recognition that among the bottom-dwelling and inshore taxa, Diodontidae show the greatest change. In their view, this change was so great that it alone was responsible for the impression that early fish-bone assemblages are different from later assemblages. They assert that Dye did not “consider how the abundance of Diodontidae (spiny pufferfishes) in the later period might be the result of differential preservation and the numerous and highly distinctive (and thus identifiable) spines from members of this family” (Sweeney et al. 1993:233). However, they neglect to note that early-period assemblages also contain identified specimens of Diodontidae, though in small numbers. Because the number of identifiable elements in the skeletons of the various Diodontidae taxa presumably did not change over the period represented by the Marquesan sequence, it is safe to assume that the remains of this taxon would be similarly overrepresented in the early period assemblages, thus obviating any

Table 1. RANK ORDERS OF TAXA BY WEIGHT FROM THE HANE DUNE SITE AND 5 NORTHERN MARQUESAN SITES (INCLUDING HANE DUNE SITE)

TAXON	HANE DUNE SITE			5 SITES		
	I	II	IV	I	II	IV
Bird	1	5	6	1	5	6
Shell	2	1	1	2	1	1
Marine Invertebrate	3	2	3	3	2	4
Turtle	4	4	5	4	4	5
Fish	5	3	2	5	3	3
Pig	6	6	4	6	6	2

Source: Kirch 1973 : Tables 1–5, 7, 9.

potential problem. This common-sense point is explicitly made by Grayson, who notes that the critique

that different species have different numbers of identifiable elements also poses no insurmountable problem . . . since faunal analysts are generally interested in studying changes in *relative* taxonomic abundances across space or through time, and since the number of identifiable elements per taxon is, or should be, a function of the particular taxa being identified, this critique applies only to single faunal assemblages. (Grayson 1984 : 25, emphasis in original)

Thus, there is no basis for removing Diodontidae from the reanalysis.

Sweeney and colleagues go on to calculate a correlation statistic on the rank orders of the taxa, the values of which are reported in an errata page as $R_s = 0.36$ for all taxa and $R_s = 0.49$ when Diodontidae are removed. Based on the rank correlation coefficients, they conclude that “after the removal of the diodons, the orders . . . are highly correlated” (Sweeney et al. 1993 : 233). However, the correlation coefficient of 0.49 does not indicate that the rank abundances of taxa from the early and late periods at Hane Dune site are highly correlated, as claimed. Rather, it indicates that the rank-order abundances are significantly correlated, but the correlation is not particularly high. In other words, the assemblages do differ somewhat. This modest degree of correlation is surprising given the high likelihood that the early and late fish-bone assemblages at Hane Dune site both resulted, in large part, from fishing in the bay fronting Hane Dune. Sweeney and colleagues apparently confused the significance level of the null hypothesis test with the strength of the correlation. In this case, a modest degree of correlation was sufficient to reject the null hypothesis.

As a final step Sweeney and colleagues investigate the diversity of taxa in the early and late fish-bone assemblages. The concept of diversity has a potentially important role to play in explanations of prehistory (e.g., Neiman 1995), but its usefulness in any particular case depends upon whether the diversity of taxa in an assemblage bears any necessary relationship to the question at hand. Sweeney and colleagues (1993 : 233–234) find that two indices of diversity, richness and evenness, are similar for the early and late fish-bone assemblages minus Diodontidae and conclude that there is “no evidence to suggest a shift in diversity from off-shore and inshore taxa over time.” Even if true—a possibility decreased by the

removal of Diodontidae from the late-period assemblage with the great effect that this has on evenness—this would have no bearing on the argument put forward by Dye (1990). That argument was based on changes in the relative abundances of bottom-dwelling and inshore versus free-ranging and pelagic fishes in the early and late assemblages, and not on changes in the diversity of taxa in the assemblages. Thus, Sweeney and colleagues fail to demonstrate the potential importance of diversity measures for faunal analyses in Polynesia, a failure that has plagued attempts to apply the diversity concept elsewhere (cf. Cowgill 1989: 131).

SAMPLE SIZE EFFECTS

The decision of Sweeney and colleagues (1993) to limit reanalysis to the Hane Dune site greatly reduces the sizes of the late-period assemblages. Because sample size is a primary consideration in the definition of an assemblage, it is useful to explore the ramifications of the sample-size decline for analyses of the faunal data from Kirch (1973) and the fish-bone data from Dye (1990).

The differences between the rank order of taxa from the Hane Dune site and the five northern Marquesan sites analyzed by Kirch (which includes the Hane Dune site) are shown in Table 1. As can be seen in the table, the rank orders of the taxa in the Period I and Period II assemblages are the same for both data sets. In the Period IV assemblages, the rank orders of three taxa—marine invertebrate, fish, and pig—are different. With the exception of pig, which drops from second in abundance to fourth, however, the relative orders of the taxa are the same. Accordingly, the two Period IV data sets show a significant positive correlation ($R_s = 0.83$, $p < 0.1$). When the two Period IV data sets are compared with Period I, the R_s values show that the moderate, but insignificant, negative correlation of the data sets drawn from the five northern Marquesas sites ($R_s = -0.37$, $p > 0.3$) becomes less pronounced and retains its insignificance when the comparison is drawn with the Hane Dune site alone ($R_s = -0.14$, $p > 0.7$). Interestingly, despite the strong correlation of the two Period IV assemblages and the relatively slight differences in their correlations with the Period I assemblage, it is often asserted that Period IV assemblage of the Hane Dune site does not support the interpretation of Marquesan subsistence change that was inferred from differences between the Period I assemblage and the Period IV assemblage from the five northern Marquesas sites (Anderson et al. 1994: 49; Sweeney et al. 1993: 234). Clearly, this assertion is based on differences in the rank order of pig in the Period IV assemblages and not on differences in the values of the correlation coefficients. But there is no protocol for deciding which changes in rank order are worth singling out for attention or how big a change is significant. Sweeney and colleagues (1993) and Anderson and colleagues (1994) might agree among themselves that the differences in the Period IV assemblages are sufficiently large, but nothing in their presentations prevents others from taking the opposite position.

It is difficult to address the issue of sample size with the faunal data because they are reported as weights. The average weight of faunal elements differs widely among the taxa, so the units of measurement are not independent. The NISP measure used with the fish-bone assemblages is more amenable to statistical analysis, and it is possible to explore the effects of sample size in this context. Various methods have been proposed (Cowgill 1989: 133–135), but simulation provides a

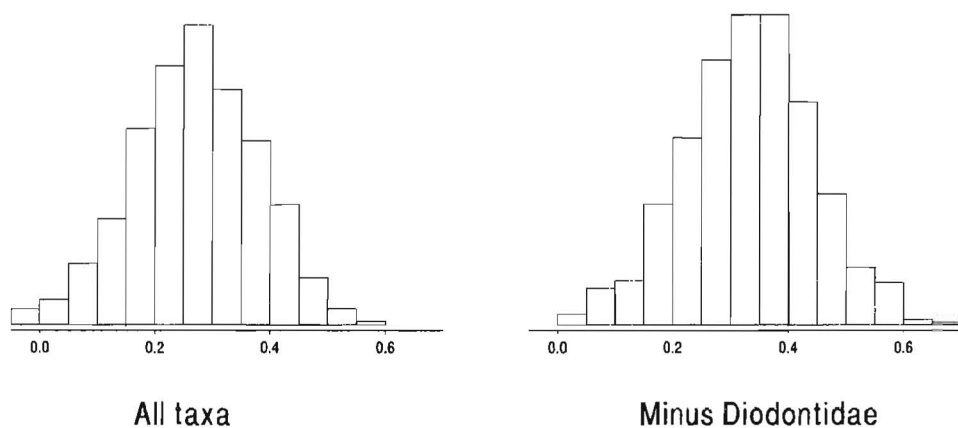


Fig. 1. Distribution of 1000 bootstrap replications of Spearman's rank correlation coefficient, from the early-period and late-period fish-bone assemblages from Hane Dune site (Dye 1990:Table 1). Left panel: all taxa, early period $n = 304$, late period $n = 100$. Right panel: all taxa minus Diodontidae, early period $n = 299$, late period $n = 57$. The sample standard deviation of both distributions is 0.11.

relatively direct approach to the problem of variability in a statistic (cf. Kintigh 1989). The standard error of the rank-order correlation coefficient is estimated here using bootstrap techniques (Efron and Tibshirani 1993:45).

The procedure used to estimate the standard error of the rank correlation coefficient draws bootstrap samples directly from the NISP data for both early and late periods. The early- and late-period bootstrap samples are tabulated, and a Spearman's rank correlation coefficient is calculated in the usual way, yielding a simulated bootstrap R_s value. This procedure is repeated 1000 times to produce a distribution of simulated bootstrap R_s values (Fig. 1). The standard error is estimated by the sample standard deviation of the bootstrap R_s values. In the simulation, the sample standard deviation stabilized after about 200 iterations of the bootstrap, a number that fits well with Efron and Tibshirani's recommendation that between 25 and 200 bootstrap samples be used to estimate the standard error of the correlation coefficient (1993:47). For the data from the Hane Dune site, the standard error of the correlation coefficient is 0.11, and this value is the same for both the full data set and the data set minus Diodontidae. Using recalculated Spearman's R_s values for these assemblages—which differ from those reported in the errata page of Sweeney and colleagues (1993) due to differences in the handling of ties and the definition of taxa—it is easy to see that there is no significant difference between the value of 0.33 ± 0.11 for the full assemblage from Hane Dune site and the value of 0.40 ± 0.11 for the assemblage without Diodontidae. As Cowgill demonstrates, large errors in correlation statistics are caused by the small number of specimens in the least abundant taxa, rather than by the total size of the assemblages (1989:134). He tentatively recommends a minimum sample size of 300. The late-period fish-bone assemblage from Hane Dune site contains only 99 NISP, and most taxa are represented by fewer than 5 NISP. The decisions to reanalyze a single site and to classify the remains using a large number of taxa render further manipulation meaningless, and assure that statistical results will be swamped by the chance errors characteristic of a small sample.

Clearly, there is a need for a protocol in interpreting R_s values for faunal data if they are to be used in the manner advocated by Sweeney and colleagues (1993). If the fish-bone example is a reasonable guide, then the 0.23 difference in R_s between comparisons of the Period I faunal assemblage with the Period IV assemblage from Hane Dune site and with the Period IV assemblage from the five northern Marquesas sites is unlikely to be significant. There would appear to be little point to reanalyzing the faunal material identified by Kirch, because the assemblage is too small to support statistical analysis. Instead, what is needed is identification of the Hane Dune site faunal material stored at the Bernice P. Bishop Museum, Honolulu, which would considerably augment the sizes of the assemblages.

THE EFFECTS OF SPATIAL AND FUNCTIONAL VARIABILITY

All of this leaves open the question posed by Sweeney and colleagues (1993) concerning the effect of spatial variability on the analyses of faunal change over time. As Anderson and colleagues (1994: 50) recognize, however, this issue was largely resolved by the results of excavations at the southern Marquesan Hanamiai site, which reproduced at a single location the faunal changes recognized by Kirch in the northern Marquesas (Rolett 1992). Rolett (1989) also found the decline in free-ranging and pelagic fish that Dye identified in the northern Marquesas. The reanalysis of fish-hook form by Anderson and colleagues shows that the shift from rotating to jabbing, which Dye cited as a corollary of the changes observed in the fish-bone assemblages, is found throughout the Marquesas at a range of different sites (1994: 43). In my view there can be little doubt now that sources of variability unrelated to time are not responsible for the patterns observed in the archaeological record. These patterns reflect changes that were played out through prehistory across the Marquesan archipelago.

DISCUSSION AND CONCLUSION

The questions about intersite and functional variability in Marquesan faunal assemblages are answered: these potential sources of variability do not unduly affect evidence for change over time. The case for changes over time in the capture of free-ranging and pelagic fish is bolstered by coeval changes throughout the archipelago in the manufacture of fishing gear types associated with their capture. Prehistoric fishing pressure was probably not sufficient to affect populations of free-ranging and pelagic fish taxa, which increases the likelihood that changes in the assemblages reflect changes in the behavior of Marquesan fishermen. Whether this made a difference in the amount or quality of available food is difficult to determine with the faunal remains alone, although Dye (1990) used evidence of starvation in the early historic period to support claims that changes in fishing practices resulted in a quantitative decline. This is an important point in Marquesan prehistory that deserves more investigation.

The case for changes in the broader faunal assemblage is bolstered by theoretical considerations of the effects of human colonization on pristine bird and shellfish populations and the length of time needed to establish a viable and reliable terrestrial production system to explain the observed patterns of change. Dye followed Kirch (Kirch and Yen 1982) in using meat weight estimates to investigate

the quantitative aspects of the observed faunal changes, but substantial improvements can be expected with improved methods (e.g., Leach and Boocock in press), and it would be interesting to apply these to the Marquesan assemblages.

An important, largely unresolved question for all Marquesan faunal analyses concerns the rate and timing of change. Rolett and Conte's (1995) redating of the Ha'atuatua sequence based on new fieldwork places initial occupation there several hundred years later than Suggs (1960:111–112; 1961:20, 181) had inferred, with important implications for both the timing and rate of changes. Anderson and colleagues (1994) advocate a similar program at the Hane Dune site. Resolution of what appears to be large errors in the estimates of the ages of deposits is needed before finer grained analyses of difference and change in the available assemblages will yield useful results.

Prognostications of progress in the investigation of subsistence with archaeological faunal assemblages are clouded by the failure of faunal analysts to report commensurable basic data. There is no agreement on which basic units of measurement should be reported: some analysts favor NISP, others weight, and still others minimum numbers of individuals, variously calculated. While there are points in favor of and against each of these measures, the failure to agree upon a standard format for reporting basic data means that comparisons between assemblages are often extremely difficult or impossible to achieve (e.g., Leach and Boocock 1993). This is an important point because comparisons between assemblages can be a useful tool for identifying potential sources of variability associated with preservation, recovery, fragmentation, identifiability, intrasite variability, and cultural disposal patterns, all of which interfere with the inference of subsistence behavior from the evidence of faunal assemblages. In this context, the diversity indices championed by Sweeney and colleagues (1993) might prove useful because richness and especially evenness can be expected to show the effects of these sources of variability.

Although much remains to be done, the history of faunal analysis in the Marquesas proves the value of identifying indications of change, even when these are not subjected to detailed statistical treatment. The indications of change revealed by Kirch (1973) and Dye (1990) are supported and have been refined by recent research. The confirmatory approach advocated by Sweeney and colleagues (1993), wherein patterns in the archaeological record must be "sufficiently verified for prehistory" militates against the discovery and communication of indications of change. Their hypothesis that "stable patterns of resource use may be ... common ... in Polynesian prehistory" (1993:235) is at least partially based on an unjustified rejection of a substantial body of evidence indicating both change over time and variability across space throughout Polynesia. The prehistoric Marquesan faunal assemblages, with their evidence for striking changes over time, add significantly to this picture of variability within Polynesia. Future investigations of these changes will likely add precision and detail to the story of the Marquesan past.

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ABSTRACT

The hypothesis that indications of change in Marquesan faunal assemblages reflect changes in prehistoric subsistence practices is challenged through reanalyses of the identified faunal remains from the Hane Dune site. An alternative hypothesis is proposed: that the supposed indications of change actually reflect intersite spatial and functional variability. Using bootstrap techniques to estimate the standard error of Spearman's rank correlation coefficient, reanalyses of the Hane Dune site assemblages are shown to be flawed by a failure to consider the effects of small sample sizes. The hypothesis that indications of change reflect intersite spatial and functional variability is weakened by the results of recent excavations. Recently reported evidence for change in Marquesan faunal and artifact assemblages supports the inference that Marquesan subsistence practices changed markedly over the course of prehistory.